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RIVAL SYSTEMS OF HEATING.

DR. BELL.

So MUCH has been said recently about the germ origin of disease, that people generally are in danger of having their attention diverted from prevalent tangible causes of disease within easy control, while catching at shadows. First among the controllable causes of ill-health in temperate and cold climates is an excessively variable or foul indoor atmosphere, due to defects in the mode of warming houses. Exposure to a temperature much below that of animal heat for any considerable time always weakens vitality and increases the susceptibility to disease. Hence, the economy of heat is a primary element in the art of preserving health. Of the common means to this end—clothing, houses, and fire—the last only is the subject of this article, and with special reference to the relative merits, from the sanitary point of view, of stoves and furnaces as compared with steam. Simply to obtain the necessary degree of temperature would be an easy matter, but ventilation must be constantly kept in view, and this cannot be secured without some sacrifice of heat. Time was when the open fire-place was regarded as the *conditio sine quâ non* of health; but, as Rumford put it, "while the draughts chill one part of the body, the rest is roasted by the fire in the fire-place, and this cannot but be injurious to health."

A close stove, everybody knows, is simply a hollow cylinder, or box, made of metal, brick, or earthenware, which is heated by a fire within it, and gives out its heat to the air by contact, and to surrounding solid objects by radiation. In an economical point of view it excels all other means of warming. The heated air from a fire-place is available to the apartment for only about twelve per cent. of the total amount of heat produced: all the rest passes up the chimney. The close stove, on the contrary, utilizes from eighty-five to ninety per cent. of the heat produced, and loses through the smoke-pipe only about as much as the open fire-place saves—ten to fifteen per cent. And herein lies the striking difference between the relative healthiness of the atmosphere heated by a close stove and an open fire-place. The amount of air which hourly passes through a close stove, heated with a brisk fire, is, on an average, equal to only about one-tenth of the capacity of the room warmed, and consequently such stove requires, if unaided, ten hours to effect a change of the atmosphere in every such apartment. Thus stagnant and heated, the air becomes filled with the impurities of respiration and cutaneous transpiration.

Moisture, too, is an important consideration. The atmosphere, whether within doors or without, can only contain a certain proportion of moisture to each cubic foot, and no more, according to temperature. At eighty degrees it is capable of containing five times as much as at thirty-two degrees. Hence, an atmosphere at thirty-two degrees, with its requisite supply of moisture, introduced into a confined space and heated up to eighty degrees, has its capacity for moisture so increased as to dry and wither everything with which it comes in contact: furniture cracks and warps, seams open in the molding, wainscoting, and doors; plants die; ophthalmia, catarrh, and bronchitis are common family complaints, and consumption is not infrequent. But this condition of house air is not peculiar to stove-heat. It is equally true of any overheated and confined atmosphere. The chief difference is, that warming the air by means of a close stove is more quickly accomplished and more easily kept up than by any other means. Sometimes, by the scorching of dust afloat in the atmosphere, an unpleasant odor is evolved which is erroneously supposed to be a special indication of impurity, caused by burning the air. It is an indication of excessive heat of the stove. But the air cannot be said to burn, in any true sense of the word, for it continues to possess its due proportion of elementary constituents. Such is the close stove and its dangers, under the most unfavorable circumstances. The Dutch stove is occasionally found in country railroad depots and similar places, where the frequent opening of doors makes amends for its deficiencies. In Russia, and other northern countries of Europe, stoves are frequently built of brick covered with porcelain, with relatively small fire-chambers near the bottom, and with winding smoke-flues which traverse many times through the structure, until nearly the whole of the heat generated is expended in it. The smoke-pipe, now comparatively cool, enters a flue in the wall and carries off the smoke only, while the heated mass of brick continues to retain heat and warm the room long after all the fuel is burned—for from eight to ten hours. If the same quantity of fuel were burned in an open fire-grate or close stove, the heat therefrom would be expended in an hour.

Stoves have been so improved in recent years, in the United States especially, and are obtainable at such moderate expense, that no excuse for the continued use of such as have been above described now exists. Indeed, so important and rapid have been the improvements in the construction of stoves in the United States within the last eight or ten years, that it is difficult to find a market for those of older date. In England, where the people continue to be wedded to open grates, and where most is said by scientific persons against the use of stoves, improvements have been exceedingly slow and complicated, and the practicability of maintaining a sufficient and equable temperature, and a wholesome atmosphere in a room warmed by a stove, is far from being realized; still less, the convenience of warming several rooms at the same time by the same means, hot-air furnaces scarcely being known.

The essentials for healthy stove-heat are a brick-lined fire-chamber, exhaust-flue for foul air, means for supplying moisture, and provision for fresh-air supply. A brick lining is requisite for the double purpose of preventing overheating, and for retaining heat in the stove. For the supply of moisture, the means are simple and easy of control, but often inadequate. An efficient foul-air shaft may be fitted to the commonest of close stoves by simply inclosing the smoke-pipe in a jacket—that is, in a pipe of two or three inches greater diameter. This should be braced round the smoke-pipe, and left open at the end next the stove. At its entry into the chimney, or in its passage through the roof of a car, as the case may be, a perforated collar should separate it from the smoke-pipe. For stoves with a short horizontal smoke-pipe, passing through a fire-board, the latter should always be raised about three inches from the floor. A smoke-pipe thus jacketed, or fire-board so raised at the bottom, affords ample provision for the escape of foul air.

The introduction of fresh air is a comparatively easy matter, when by no more special provision, then by a strip of board under the window-sash, closely fitted. The lap of the sash at the middle admits the air with a direction to the ceiling, and, consequently, without draft on any one in the room.

The experiments of Pettenkoffer have shown that under the common conditions of the atmosphere, a very considerable exchange of gases takes place through dry plastered walls, brick, and stone. And it is the common experience of sick persons that they are sensitive to drafts through walls when the wind blows, and that they frequently take cold by exposure to the windy side of the house.

All flues for the exit of foul air should be perfectly smooth and tight. Rough surfaces not only retard but retain emanations which come in contact with them. Moreover, exhaust-flues should never be placed in outer cold walls, because the greater density of the outer cold air prevents the ready ascent of the warmed and rarefied air from within. Another important consideration is the size of air-shafts. This can only be approximate, however, because the amount of air which will pass through a shaft depends in a great degree upon the relative temperatures of the inner and outer atmospheres, and the conditions of the weather, particularly the direction of the wind. As a practical average, the best observers recommend that the sectional area of both inlet and outlet shafts be 24 square inches per head; or, for buildings of three stories, one square inch for every 50 cubic feet of space; rooms below, one square inch for every 55 cubic feet; for ground floors, one square inch for every 60 cubic feet. It should be borne in mind that the friction in long flues considerably lessens the extractive power, and that the column of air in the flue increases in density as it ascends. In prisons, where the cubic space per head is comparatively small, the sectional area of the air-shafts should be at least 20 square inches per head.

Open fire-stoves combine the advantages of the open fireplace and the close stove, provide for fresh air, and economize heat. The important improvements in stoves of this kind have not only well-nigh supplanted the open fire-grate in supplying all that was ever claimed for it, but excel it in all the requisites of economy and comfort.

Hot-air furnaces are simply inclosed stoves placed outside the apartments to be warmed, and usually in cellars or basements of the buildings in which they are used. The manner of warming is virtually the same as by indirect steam-heat — by the passage of air over the surface of the heated furnace or steam-heated pipes, as the case may be, through flues or pipes provided with registers. The most essential condition of satisfactory warming by a hot-air furnace is a good chimney-draught, which should always be stronger than that of the hot-air pipes through which the warmed air is conveyed into the rooms, and this can be measured by the force with which it passes through the registers. A chimney-draught thus regulated effectively removes all emanations; for, if the chimney-draught exceeds that of the hot-air pipes, all the gaseous emanations from the inside of the furnace, and if it have crevices, or is of cast-iron and overheated, all around it on the outside, will be drawn into the chimney. Closely connected with this requirement for the chimney-draught is the regulating apparatus for governing the combustion of fuel — the draught of the furnace. This should all be below the grate; there should be no dampers in the smoke-pipe or chimney, and all joints below and about the grate should be air-tight. The fire-pot should be lined with brick and entirely within the furnace, but separate from it, so that the fresh air to be warmed cannot come in contact with the fuel-chamber.

It should go without saying that the air which passes from furnaces into living-rooms should always be taken from out-of-doors, and be conveyed in perfectly clean air-tight shafts to and around the base of the furnace. Preferably, the inlet of the shaft, or cold-air box, should be carried down and curved at a level (of its upper surface) with the bottom, and full width of the furnace. Thus applied, the air is equally distributed for warming and ascent through the hot-air pipes to the apartments to be warmed. On the outside, the cold-air shaft should be turned up several feet from the surface of the ground, and its mouth protected from dust by an air-strainer. A simple but effectual way is to cover the mouth with wire cloth, and over this to lay a piece of loose cotton wadding. This may be kept in place with a weight made of a few crossings of heavy wire, and it should be changed every few months. And here, too, outside the house, should be placed the diaphragm for regulating the amount of cold-air supply, and not, as commonly, in the cellar.

As the best means of regulating the temperature and purity of the atmosphere from hot-air furnaces, it is necessary to provide sufficiently large channels for both the inlet of fresh air and its distribution through the hot-air pipes. The area of the smallest part of the inlet (or inlets, for it is sometimes better to have more than one) should be about one-sixth of a square foot for every pound of coal estimated to be burned hourly, in cold weather; and to prevent, in a measure, the inconvenience of one hot-air pipe drawing from another, the collective area of the hot-air pipes should not be more than one-sixth greater than the area of the cold-air inlet. These proportions will admit the hot air at a temperature of about 120°, when at zero outside, and the velocity through the registers will not exceed five feet per second.

A large heating surface of the furnace is a well-recognized condition of both economy and efficiency. As a rule, there should be ten square feet of heating surface to every pound of coal consumed per hour, when in active combustion; and the grate area should be about one-fiftieth of that of the heating surface. For the deficiency of heat, or the failure of some of the hot-air pipes of hot-air furnaces in certain winds and weathers in large houses or specially exposed rooms, the best addendum is an open fire-grate. With this provision in northerly rooms, to be used occasionally, hot-air furnaces may be made to produce all the advantages of steam-heat in even the largest dwelling-houses.

Steam-heat may well be compared with stove and furnace heat: stove-heat corresponds to direct radiation by steam, and furnace-heat to indirect. The supply of fresh air from the outside to and over the hot-air furnace, and through hot-air flues into the rooms through registers, is virtually the same as when it is conveyed by means of steam-heated flues in the walls. Exhaust-flues, for getting rid of foul air, are equally essential. The stove, as representing direct radiation in the same manner as the steam coil, or plate, in the room, has the advantage over the latter of some exhaust of foul air, however little, even when the smoke-pipe is not jacketed, for the steam-heat has none. In comparison with open stove-heat, steam-heat is at still greater disadvantage; for open stoves supply all the qualities of complete radiation — the introduction of fresh air and the escape of foul — to a degree wholly unattainable by steam-heat, whether direct or indirect, or by hot-air furnaces, which always require special provision for the escape of foul air.

The advantage of stove and furnace heat over steam may be summed up thus: It is more economical, more uniform, more easy of management, more suitable for small areas to be warmed, and is free from the noises and dangers of steam. Irregularities of the fire in steam-heating are a constant source of inconvenience, and sometimes of danger. The going down of the fire during the night-time, or its neglect for a few hours at any time, is followed by condensation of the steam. On the addition of fuel and increase of heat, steam again flows quickly into the pipes where a partial vacuum has formed, and here, on coming in contact with the condensed water, it drives the water violently and creates such shocks as sometimes occasion explosions; or, at least, produces very disagreeable noises and general uneasiness, and frequently causes cracks and leaks. Hence direct steam-heat, which for warming purposes alone is altogether superior to indirect, has been well-nigh abandoned. Indirect steam-heat places the leaks out of sight, but they commonly lead to mischief, and require special and expensive provision for access and repair.

A. N. BELL.

PROF. TROWBRIDGE.

TO THE architect and sanitary engineer of the present day the terms warming and ventilation have certain technical meanings, and when employed together refer to systematic arrangements and appliances in the construction of dwellings, public buildings, churches, and halls of audience, by which not only may suitable temperatures be maintained in these structures, but proper quantities of pure and fresh air supplied continuously. It may be laid down as a fundamental principle that the warming and the ventilation of dwelling-places are equally indispensable to health, and that they are, to a great extent, inseparable in their relation to each other, and, ordinarily, in the appliances by which they are effected.

Four modes of heating, which furnish at the same time different degrees of ventilation, comprise all in common use, viz.: the open fire-place, the close stove, the hot-air furnace, and the steam-heating apparatus. A comparison of these methods involves, for each, the cost of the apparatus and its durability, the cost of fuel and attendance, and the efficiency of the apparatus for heating and ventilation.

The open fire and the stove furnish means for a constant supply of heat, through combustion of fuel, within the room to be heated. The open fire gives off its heat to the walls and objects in a room only by radiation from the burning fuel, all the air that passes the heated surfaces of the fire-place going directly up the chimney. Hence, this method is inefficient for heating, especially when the walls of the room in which the fire is placed are greatly exposed to outside cooling influences. Moreover, much more air than is necessary for combustion passes up the chimney, from the very nature of its construction; and as this air must pass through the room to the chimney, it is difficult in general to avoid cold currents of air. Remote corners are apt to receive little heat directly, and the full effect of the open fire for a dwelling, requiring as it must, a fire for each room, is attained only at a great expense of fuel. While the first cost of the fireplace may not be great, the cost of fuel, except when such open fires are mere adjuncts to some other system, renders this mode of heating, as houses are now constructed and occupied, quite out of the question for the ordinary householder. As regards ventilation, however, the open fire is of all systems the most admirable.

The second mode of heating, the close stove, is doubtless of all modes the most universally practiced at the present day. Whether the stove be a simple structure of cast or wrought iron, having an interior chamber for the combustion of fuel, with a plain wrought-iron pipe to lead away the gases of combustion, or whether this simple structure be incased or provided with additional chambers and pipes for the more extended circulation of the heated gases, and to furnish the greatest possible heating surface, the statistics of manufacture alone furnish evidence that there is some special advantage in this mode of heating which commends it to popular favor. It is not difficult to account for the preference: the stove can be placed at little expense in any room of any building where there is a flue for carrying off the smoke and the gases of combustion. The activity of the fire can be modified at will to suit any degree of external temperature; and as it is generally employed with the minimum amount of ventilation, and often with almost none at all, the economy of heat is all that can be desired. But in proportion as an active and sufficient ventilation is demanded, this efficiency of heating disappears; and since the usual practice is to trust for ventilation to the accidental influx of air through crevices in the window and door casings, the use of stoves is quite sure to lead to a vitiated atmosphere. Owing to the fact that the heating appliances of both the open fire and the stove are confined almost entirely to the room or apartment in which the fuel is burned, the heating of a building comprising many apartments, by these methods, can only be accomplished by increasing the number of fires or stoves. The economy which might be practicable for a single room then disappears to a great extent, owing to the increased cost of attendance, as well as waste.

Two modes of heating are in vogue by which the demands of economy and comfort are then met, viz.: the hot-air furnace and the steam-heating apparatus. The hot-air furnace is simply an encased stove outside of, and away from, the apartments to be heated, generally in the cellar or basement of a building. The casing or chamber within which the stove is placed is put in communication with the external air by an inlet conduit, which serves the double purpose of furnishing air for combustion and for supplying a number of rooms with heated air. To effect this twofold purpose, there is a chimney direct from the stove for the removal of the gases of combustion, and one or more flues leading from the air-chamber around the stove, with branches for the different apartments, for that portion of the air which comes in contact with the heated surfaces of the stove and casing, and which then passes to the rooms. The air is usually heated to a temperature of 250 to 400 degrees, and by mixture with cold air may be brought down to 150 or 200 degrees, at which temperature it will enter the rooms. Air at these high temperatures must be further reduced in temperature and mingled with cold air in the rooms to be warmed, and for effecting this object reliance is generally placed on the accidental leakage at doors and windows. The expulsion of the heated air is accomplished by a spontaneous draft through flues from the heated apartments to the roof, or into halls and thence to upper stories.

A single furnace may thus heat very economically an ordinary dwelling; but the disadvantages and defects of the system are numerous. Beyond a certain limited distance from the furnace the difficulty of conveying heated currents in this manner increases very rapidly; and where there are branch ducts leading to many rooms, one branch may overpower another, causing excessive heat in one room and a deficiency in another. The proper ventilation of apartments is difficult, and the highly heated currents, having an increased capacity for moisture, are apt to convert the rooms to be heated into drying chambers, to an extent that is neither agreeable nor healthful. A few open fires, arranged to produce proper ventilation, mitigate very much some of these evils. For large buildings several hot-air furnaces must be provided, and the economy is proportionally diminished.

All of the above-described methods have been supplanted to some extent, in this country at least, by steam-heating apparatus, or its practical equivalent in limited circuits, the hot-water apparatus. Even for ordinary dwellings, this system is being gradually extended; while for large blocks, such as apartment houses, hotels, manufacturing establishments, school-houses, and other large structures, the system is so greatly in demand as to have given rise to new and extensive industries devoted to the manufacture and installment of the necessary apparatus.

Steam heating is characterized by the fact that the heat is generated in the furnace of a boiler either within or without the walls of the building to be heated, the heat of combustion being transferred to water, which, being vaporized, constitutes the medium by which the heat is conveyed in comparatively small pipes to the points where it is utilized for heating purposes. Two distinct methods of utilizing this heat are practiced. In one the steam pipes are carried, by the most convenient course, directly into the room or space to be heated, where, by convolutions of the pipes, or what are known as radiators, an extended heating surface is furnished to the room. These coils, or radiators, give off heat both by radiation and by contact with the air, which is kept slowly circulating, as in the case of a close stove; and it is evident that only a feeble, or at least uncertain, ventilation is possible, except through special arrangements made for introducing fresh air. These heated coils are, in effect, identical with close stoves, the only difference being that the surfaces of the coils can never be heated to a degree higher than that of the steam,—practically, never higher than three hundred and ten nor lower than two hundred and fifteen or two hundred and twenty degrees Fahr., while the surface of the close stove may, under some circumstances, approach nine hundred and fifty degrees.

Active and sufficient ventilation may be attained with these coils, however, if they are placed in such a way that cool air, introduced through openings,— as, for example, under windows,— will mingle directly with the heated air rising from the radiators, and then be deflected upward to be mixed with the general circulation, and discharged through ventilating flues. Of course, such active ventilation can only be attained at the expense of additional heat.

The other method, called by a strange misconception "indirect radiation," consists in conveying the steam from the boiler to small chambers constructed for the purpose, in the basement, directly beneath the rooms to be warmed. Here the steam pipe is extended into a coil, or an equivalent arrangement, by which a large amount of steam-heated surface is exposed. Flues for heated air lead from the roof of the chamber to the various rooms to be heated; an inlet duct for fresh air enters the bottom of the chamber, and the coils, or "radiators" are so arranged that the air in rising comes in contact with the heated surfaces, and passes to the apartments to be warmed with the temperature increased to seventy or one hundred degrees Fahr. Low temperature currents only are generated; and as the proper action of the apparatus can be kept up only by a continuity of flow into and out of the space to be heated, the two effects of heating and ventilation are most effectively combined.

A comparison of these various methods must include the cost of the apparatus, the cost of attendance, the cost of fuel, and the incidental advantages and disadvantages belonging to each. The open fire-place possesses the advantage of giving thorough ventilation, but it is the most expensive in fuel. The close stove is highly advantageous in point of economy, where there is little ventilation, and as this is apt to be the rule, it is perhaps the least healthful of all methods as generally applied. Both of these methods become costly in attendance as well as in fuel when the heating of dwellings of many rooms is required, and are inapplicable to large structures and public buildings as they are now constructed. The hot-air furnace system is of all the most difficult to manage, so far as uniformity and control of temperature is concerned. The danger from fire, the dust, the defective ventilation, and the impracticability of heating more than a limited space by a single hot-air furnace are other defects inherent in this system. Steam heating involves greater first cost in apparatus than any other system. When this cost and the cost of attendance and repair are taken for a series of years, however, it is conceded that there is but little choice between hot-air furnaces and steam-heating apparatus as regards economy.

The special advantages of steam heating are: 1st. The almost absolute freedom from risk of fire when the boiler is outside of the walls of the building to be heated, and the comparative immunity under all circumstances. 2d. When the mode of heating is the indirect system, with box coils or heaters in the basement, a most thorough ventilation may be secured, and it is in fact concomitant with the heating. 3d. Whatever may be the distance of the rooms from the source of heat, a simple steam pipe of small diameter conveys the heat. From the indirect heaters underneath the apartments to be heated, a vertical flue to each apartment places the flow of the low heated currents of air under the absolute control of the occupants of the apartment. Uniformity of temperature, with certainty of control, may be thus secured. 4th. Proper hygrometric conditions of the air are better attained. As this system supplies large volumes of air heated only slightly above the external temperature, there is but little change in the relative degree of moisture of the air as it passes through the apparatus. 5th. No injurious gases can pass from the furnace into the air flues. 6th. When the method of heating is by direct radiation in the rooms, the advantages of steadiness and control of temperature, sufficient moisture and good ventilation, are not always secured; but this is rather the fault of design, since all these requirements are quite within the reach of ordinary contrivances. 7th. One of the conspicuous advantages of steam heating is that the most extensive buildings, whole blocks, and even large districts of a city, may be heated from one source, the steam at the same time furnishing power where needed, for ventilation or other purposes, and being immediately available also for extinguishing fires, either directly or through force pumps.

It is only to be remarked, finally, that the most thoughtful among our physicians and sanitary advisers realize with anxiety the fact that there is a growing abuse of all these systems, except the open fire, in providing too much heat and too little ventilation. There is no mode of heating which lends itself to the correction of this evil so readily, however, as the steam-heating method. With proper care on the part of architects in arranging inlet ducts for fresh air, and ventilating flues heated by steam coils to accelerate the draft, any desirable degree of ventilation with low temperature currents may be secured. Such arrangements should, however, be studied in advance, and form principal elements in the design of a building, instead of being wholly subordinate, as is commonly the custom, to less important architectural features. It should be regarded as a fundamental principle in architecture, that the first and most important problem to be studied, after the general design of a building is determined, is the proper positions and magnitudes of heating and ventilating appliances for the structure as a whole, and for each room in particular; and not only should the details of the main and cross walls be modified and adapted to these arrangements where it is necessary, but no question of mere architectural propriety or appearance, nor even of convenience in use, should be allowed to interfere with objects so important to health as good and sufficient warming and ventilation.

W. P. TROWBRIDGE.